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LIFE HISTORY & ECONOMIC STUDIES
ON BROMUS TECTORUM

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ON BROMUS TECTORUM

by

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LIFE HISTORY AND ECONOMIC STUDIES ON BROMUS TECTORUM.

INTRODUCTION

Bromus tectorum L., best known to stockmen as cheatgrass, downy brome or downy chess, is an introduced European species that has spread to practically every state in the union. It is common in waste places, abandoned fields, eroded areas and on overgrazed range lands. Under certain conditions, especially in cultivated fields and gardens, it may become a pestiferous weed. In general, however, its habitat is confined to areas where the natural vegetation has been reduced by adverse environmental conditions. On such areas the plant assumes only a temporary influence over the other species and with proper use and treatment these lands will return to their natural plant cover.

Statements and articles of a general nature[5,8,10,12] concerning the grass are common. So far as is known, however, there have been no actual studies made of its life history or the role it plays in the successional trend of vegetation in the grasslands of western Montana. Neither has there been any attempt to summarize under one head all the known facts concerning the plant. Because it offers a management problem on many acres of our western grazing lands, and since it is being considered more critically in carrying capacity and range stocking estimates, a generalized study of the grass has seemed worth while. The laboratory studies involved were carried out at Missoula, Montana and the field studies were made in Missoula and Sanders Counties, in which localities the bunchgrass type is well represented.

METHODS AND MATERIALS

Personal observations and experiments as noted in this paper were carried out by the writer during the period between September 1937 and April 1938.

Germination tests were run in the laboratory at room temperatures by exposing the seed between layers of moist absorbent paper in porcelain germinating dishes. Duplicate lots of 400 seeds were used for each test and at the same time a comparative test was made with 1 or more other grass species. Each test was allowed to run 20 days with counts of germinated seed being made at 5 day intervals. The results obtained and noted in the various tables are averages of the duplicate lots.

The effect of freezing seed in moist soil and in the dry state was tested for Bromus tectorum and, for comparative purposes, Agropyron spicatum and A. cristatum. From seed harvested in the fall of 1937, duplicate lots of these 3 species were placed out of doors in air-tight and moisture-proof containers for the winter period of 1937-38. A second series was exposed to over-wintering conditions in a thin cloth container which was covered with soil to a depth of approximately ½ inch. All seeds were collected in April, 1938, and germination tests run in the laboratory.

Growth studies of roots and shoots were made from seedlings grown in the laboratory. The seeds were planted to a depth of ½ inch in individual flower pots filled with soil obtained from the grasslands adjacent to Missoula. Measurements were taken of 5 plants at 5 day intervals following emergence. The averages for the 5 plants were recorded.

Competitive studies of seedlings were made in the laboratory on a small scale. The seed was sown at a depth of ½ inch in a prepared seed-bed of screened grassland soil. The plants were watered at intervals frequent enough to keep the soil damp immediately below the surface. Measurements were taken of the height growth at 5 day intervals. Four weeks after emergence, the seedlings were watered for the last time and daily observations were made thereafter of height growth, evidence of wilting and death of individual plants.

Field studies involving the succession and dominance of Bromus tectorum were made by the use of study plots, 5 square feet in size. These plots were placed at definite intervals throughout the areas studied. Data were collected on all grasses falling within the plots. The procedure followed that noted by Weaver and Clements[15] and Hanson and Love[8] in their descriptions of count-list and area-list quadrats. Analysis of the data obtained by Hanson and Love[8] in their comparisons of 0.5 and 1 square centimeter quadrats shows little variation for grass species on quadrats of these two sizes. While the larger quadrat is recommended for studies of grassland vegetation, the smaller one was more nearly approximated in size by the plots used in the Bromus tectorum studies. Since data on grasses only were obtained, however, they appeared to be sufficiently large.

Burning experiments were conducted in the field by the use of a gasoline torch. Admittedly, this subjected the vegetation and seed to a much higher temperature than would reasonably be expected in ordinary grass fires. The results obtained, however, indicate that even this ex-

treme heat was not sufficient to kill all the _Bromus tectorum_ seed. In conjunction with the burning experiments, the actual effect of heat on seed viability was determined by exposing seeds of 4 different grass species to different degrees of temperature for varying periods of time in a Freas oven.

Data on forage values were obtained through the courtesy of L. C. Hurtt of the Northern Rocky Mountain Forest and Range Experiment Station and from the literature.

DESCRIPTION OF BROMUS TECTORUM

Bromus tectorum is a rather slender annual or winter annual varying in height from 10 or 12 cm. to 60 cm. or more (Figure 1). The culms are more or less glabrous while the leaves are flat, pubescent throughout, 4 to 9 mm. wide and from 5 to 18 cm. long. The leaf sheath is pubescent and closed (Figure 2). The roots are fine, shallow and fibrous. Individual plants that stool may assume a bunchgrass appearance[5].

The inflorescence is in the form of a rather dense or open, drooping panicle. The spikelets (Figure 2) are 10 to 20 mm. long, 5- to 8-flowered and average 30 per rachis. The rachilla disarticulates above the glumes and between the florets. The glumes are unequal, villous, the first being 5 to 8 mm. long and 1-nerved while the second is 7 to 10 mm. long and 3-nerved. The lemma is lanceolate, villous or pilose, 7-nerved, 10 to 15 mm. long, awned, with the awn inserted just below the 2-toothed apex and exceeding the lemma in length. The palea is shorter than the lemma, 2-keeled and ciliate on the keels. The ovary is crowned with a villous appendage and the stigmas are plumose. Depending on locality, the flowering period ranges from May to July or even as late as September.

The seed is linear, acuminate at the tip and truncate at the base. It is well supplied with endosperm and is glabrous, hard, reddish-brown in color and approximately 9 mm. long and 1.5 mm. wide. It is deeply grooved on the under side while the upper surface has a shallow groove which is prominent only towards the center of the seed.

The variety *nudus* is distinguished from *B. tectorum* by its smooth florets.

FIG. 1. - Single plant of Bromus tectorum, illustrating its growth habit.

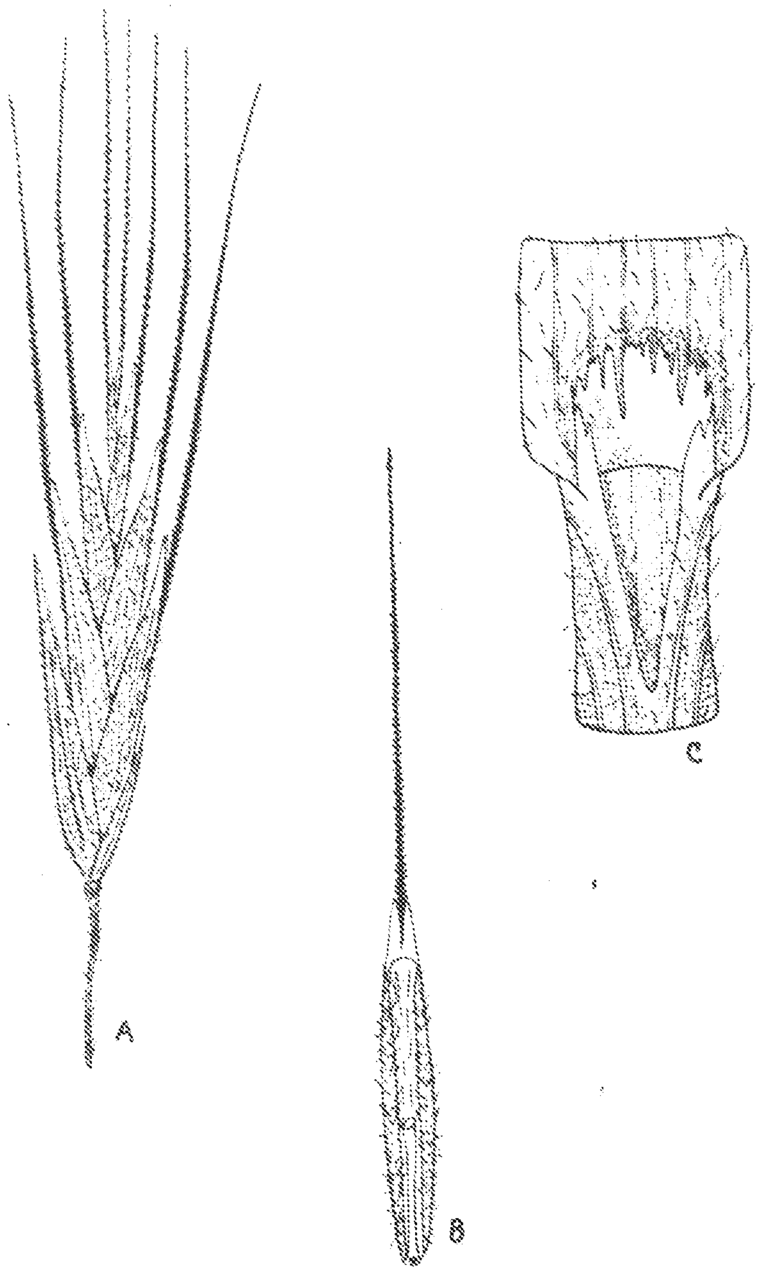

FIG. 2. - *Bromus tectorum*. A, spikelet, x 4; B, floret, x 4; C, base of leaf blade showing sheath and ligule, x 7.

SMUT INFECTION

At several-year intervals *Bromus tectorum* is attacked by a smut (*Ustilago bromivora* Fisch. and Waldh.) which greatly reduces the stand temporarily on some areas although the grass soon reestablishes itself[3].

The sori of the smut are naked and appear as black, powdery masses at maturity. Infection is very evident at the time the grass is in flower and at this time the spores are disseminated by the wind to healthy plants. Smuts of this type infect the plant through the young ovaries of normal heads where an internal mycelium is developed within the seed[8]. As germination and growth of the grass progress, the mycelium keeps pace with the growing points of the seedling and its presence is evident only when the heads are formed.

As a general rule, if an individual is smutted the infection is common to the entire plant. Exceptions to this, however, are common and an infected plant that has stooled may have individual tillers that are entirely free from the smut. Likewise, an individual head may be wholly or partially smutted.

Infections in a given stand appear to be most common on north and east slopes where as much as 85 percent of the stand may be smutted. On south and west slopes the infection is milder and it is uncommon to find the smut on more than 20 percent of the stand.

HISTORY, DISTRIBUTION AND HABITAT

Early and reasonably authentic references to *Bromus tectorum* in this country are quite scarce. Alphonso Wood's 1861 edition of his "Class-Book of Botany" indicates that it had been collected in Pennsylvania prior to that time. Basil Sollers lists it in 1893 in his "Check-List of Plants Compiled from the Vicinity of Baltimore"[9]. Asa Gray's manuals first mention the plant in the 6th edition of 1890. Two of the earliest references to the grass in western floras are to be noted in Howell's "Flora of Northwest America" (1903) and Piper's "Flora of Washington" (1906).

Early collections of the grass were made by Cartell in New York and Jackson in Pennsylvania prior to 1861[10]. In 1878 it was collected on Long Island by E. S. Miller and in 1886, in the vicinity of Chicago, Illinois, by Agnes Chase and E. J. Hill*. It was collected in 1893 in Washington by Sandberg and Leiberg, in 1894 in Utah by Marcus E. Jones, in 1895 in Colorado by C. S. Crandall and in 1900 in Wyoming by Aven Nelson.**

While definite information is lacking, it appears from the above information that the plant was introduced into the eastern part of the United States sometime about the middle of the 19th century and subsequently spread westward, reaching the far western states in the late 1800's or early 1900's. The possibility remains, however, that the grass may

* Information obtained from correspondence with W. A. Dayton, Branch of Research, U. S. Forest Service, Washington, D. C.

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have been introduced directly into the west and the lack of an early flora or manual of flowering plants of that region prevented its introduction into botanical literature.

Hitchcock[7] reports Bromus tectorum as being present throughout the United States with the exception of North Dakota, Texas and the extreme southeastern part. In the three Pacific Coast states it is generally confined to those portions of the states lying east of the Sierra Nevada and Cascade Mountain ranges.

The grass is not exacting in its habitat requirements. It generally secures its foothold in a given locality on areas where the natural cover has been disturbed or destroyed through the media of overgrazing, burning, cultivation or erosion. On eroded areas it may occupy soils that are of a B or C horizon type. In contrast, it may also be found on soils of the highest fertility. It is not common in very moist situations but neither is it found in abundance on sites of extreme arid conditions. It requires plenty of light and its best development is indicated in open grassland types, especially on south and west slopes. It is occasionally found in the ponderosa pine type but then usually in small, isolated patches where the soil has been disturbed. It seldom occurs in abundance at elevations higher than 6000 feet.

GERMINATION AND GROWTH

In the natural state the seeds of *Bromus tectorum* ripen during the summer and early fall months and fall to the ground shortly after maturity and germinate upon the advent of favorable weather conditions. Such germination invariably takes place during the months of September and October at which time moisture conditions appear to be most favorable. On good sites growth resulting from this fall germination may become very luxuriant but, generally, the vegetative activity of the plant is confined to stooling and the young seedling seldom exceeds 10 cm. in length and more often approximates 5 cm.

Germination. - The viability of a current years seed crop of *Bromus tectorum* was determined in the fall of 1937 by germination tests in the laboratory. For comparison, and because they represent an integral part of the western Montana grasslands, seeds of bluebunch wheatgrass (*Agropyron spicatum* (Pursh.) Scribn. and Smith), Idaho fescue (*Festuca idahoensis* Elmer.) and Sandberg bluegrass (*Poa secunda* Presl.) were tested at the same time. Samples of crested wheatgrass (*Agropyron cristatum* (L) Gaertn.) were also germinated. All seeds were collected at the same time and from the same general locality so that there would be few or no variations in germination percentage due to environmental conditions.

The germination percentage of each species at 5 day intervals is shown in Table 1. The data show that *Bromus tectorum* seed is very viable shortly after maturity and under favorable conditions will germinate rapidly, reaching 90.50 percentage within the first 5 days.

Table 1.- Germination percentage of various grasses

Species	Germination percentages in 5 day intervals			
	5 Days	10 Days	15 Days	20 Days
Bromus tectorum	14.50	99.75	99.75	99.75
Agropyron spicatum	34.75	84.00	93.00	93.50
Agropyron cristatum	64.00	98.00	98.50	98.50
Festuca idahoensis	68.50	80.50	94.00	94.50
Poa secunda	61.75	71.25	73.75	81.25

The germination of the seed of the other species was somewhat more delayed but the final results at the end of 20 days show a high percentage for each, especially *Agropyron cristatum* and *Festuca idahoensis*.

Germination of Over-wintering Seeds.- The results obtained by Blake[1] and Nichols[11] in their experiments with frozen seed suggested a similar study with seeds of *Bromus tectorum*. Comparative tests were also made with seeds of *Agropyron spicatum* and *Agropyron cristatum*.

From seed gathered in the fall of 1937, duplicate lots of 400 of each species were placed out of doors in air-tight and moisture-proof containers for the winter period of 1937-38. In this manner they were subjected to dry freezing and temperature variations only. A second series was placed out of doors in thin cloth containers and covered with soil to a depth of approximately ½ inch. These seeds were thus subjected to all the over-wintering variations of both temperature and moisture.

During the forepart of April 1938, all the seed was collected and germinated in the laboratory. Lots of 400 seeds of each species that had been stored in the laboratory over winter were germinated for check purposes.

The results are indicated in Table 8.

Table 8. - Percentage germination of seeds subjected to dry and wet freezing conditions.

Species	Germination percentage		
	Unfrozen	Dry freezing	Wet freezing
Bromus tectorum	99.00	99.75	3.00
Agropyron spicatum	86.75	65.00	38.00
Agropyron cristatum	94.00	68.00	63.00

The dry frozen seed of Agropyron spicatum and A. cristatum showed a lower percentage of germination than the seed that was stored in the laboratory. The viability of Bromus tectorum remained normal. The seed of Bromus tectorum that was subjected to freezing conditions in moist soil showed a very marked reaction since only 3 percent germinated. Under similar conditions the seed of the other two species also showed a drop in percentage germination with the greatest variation being evident in Agropyron spicatum.

Paralleling this experiment was a series of observations made in October of 1937 on 10 different areas supporting almost pure stands of Bromus tectorum. On all areas there was evidence of fall germination and fall growth of seedlings. Several examinations of the same areas during March and April of the following year showed no evidence of any spring germination and all seedlings present were those that had over-wintered as such.

Growth Rate of Seedlings.- During the winter of 1937-38, laboratory studies were made of the rate of root and shoot growth of Bromus tectorum seedlings as compared to those of Agropyron spicatum. This comparison was made because these two grasses represent extremes in plant succession. Examinations were

made at 5 day intervals following emergence. The development of the seedlings for these periods are shown in Figure 3.

It is to be noted that for the first 10 days growth appeared to be about the same for each species. *Bromus tectorum*, however, began to show more development of secondary and tertiary rootlets. At about the 15th day after emergence the ligule, collar and sheath of the seedlings began to assume the definite characteristics of older plants. At the end of 30 days the seedlings of *Bromus tectorum* were distinctly the more vigorous plants, exceeding those of *Agropyron spicatum* in both shoot growth and root development.

Competition Studies.-- In a simple experiment involving competition between *Bromus tectorum* and *Agropyron spicatum* seedlings under control conditions, seeds of the two grasses were planted in mixture in a prepared seed bed in the laboratory. The density of the planting was determined from the average number of *Bromus tectorum* plants per square foot found growing in the field under natural conditions. The number of seeds planted of each species was determined from the germination percentage of each (Table 1). Thus, to insure a stand of equal numbers of the two grasses, 119 seeds of *Agropyron spicatum* were sown to each 100 seeds of *Bromus tectorum*.

The seedlings of *Bromus tectorum* appeared above the soil surface approximately 1½ days before those of *Agropyron spicatum* and made more growth from the start. At the end of 4 weeks the seedlings of the former had reached an average height of 16 cm., while those of the latter were 14½ cm. tall. At this period of growth the plants were watered for the last time.

The seedlings of *Agropyron spicatum* reacted first to the adverse conditions arising from a lack of water. Seven days after the last watering,

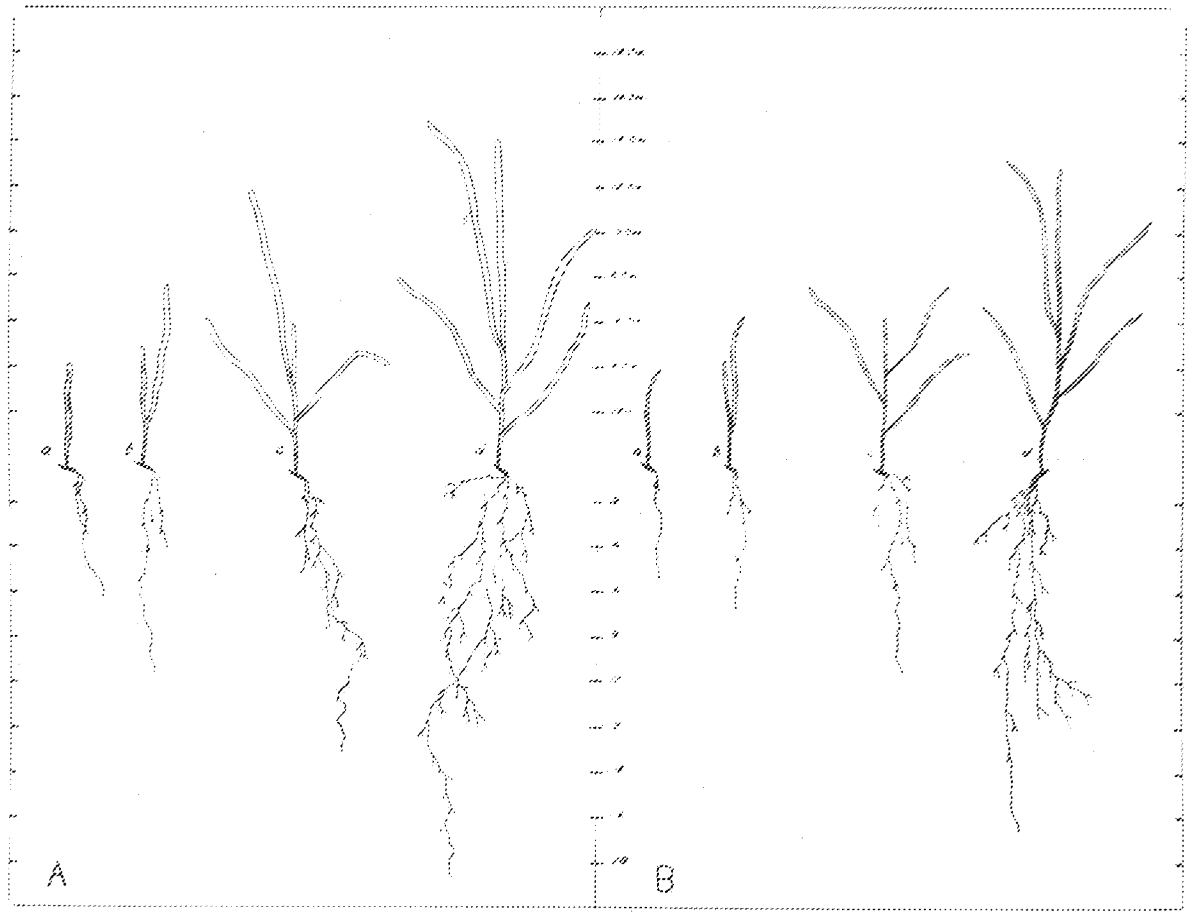

Fig. 3. - Comparison of the root and shoot development of *Bromus tectorum* (A) and *Agropyron spicatum* (B); *a*, 6 days after emergence; *b*, 10 days after emergence; *c*, 20 days after emergence; *d*, 30 days after emergence.

the growth slackened noticeably (Figure 6) and ceased entirely at the end of 12 days. Wilting was first noticed at the end of 9 days. The *Bromus tectorum* seedlings were more hardy and reacted more slowly. The growth rate lowered markedly after the seedlings were 10 days without water and further development ceased after 15 days. Wilting was first noticed at the end of 12 days. Permanent wilting and death of individual plants of *Agropyron spicatum* was first evident 20 days after the last watering while 24 days had passed before *Bromus tectorum* reacted similarly.

Discussion and Conclusions.- The seed of *Bromus tectorum* is extremely viable and under favorable conditions germinates very rapidly, reaching as high as 95.80 percent within the first 5 days and its maximum in 10 days. The germination of native grasses is somewhat more delayed but results at the end of a 30 day test show a high percentage for all species tested. It is entirely probable that the high germination figures obtained from these experiments might not be common for seed maturing on the same area in different years, or from seed obtained in other localities. Blake[1] noticed inconsistencies in all her experiments, both seasonal and from year to year.

A definite drop in the germination was observed for frozen seed, more so with seed subjected to moist freezing conditions in the soil. This is especially true of *Bromus tectorum*. The results obtained in germinating wet, frozen seeds of this species was practically negligible. These observations correlated with the apparent lack of germination of over-wintering seeds in the natural state seem to indicate that the grass might act entirely as a winter annual and not complete its life cycle in any given year.

The rate of growth of *Bromus tectorum* seedlings is somewhat faster than for those of *Agropyron spicatum*. Thirty day old seedlings show both a better root and shoot development and, in general, appear to be the more vigorous plants. Under competitive conditions the seedlings of *Bromus tectorum* make

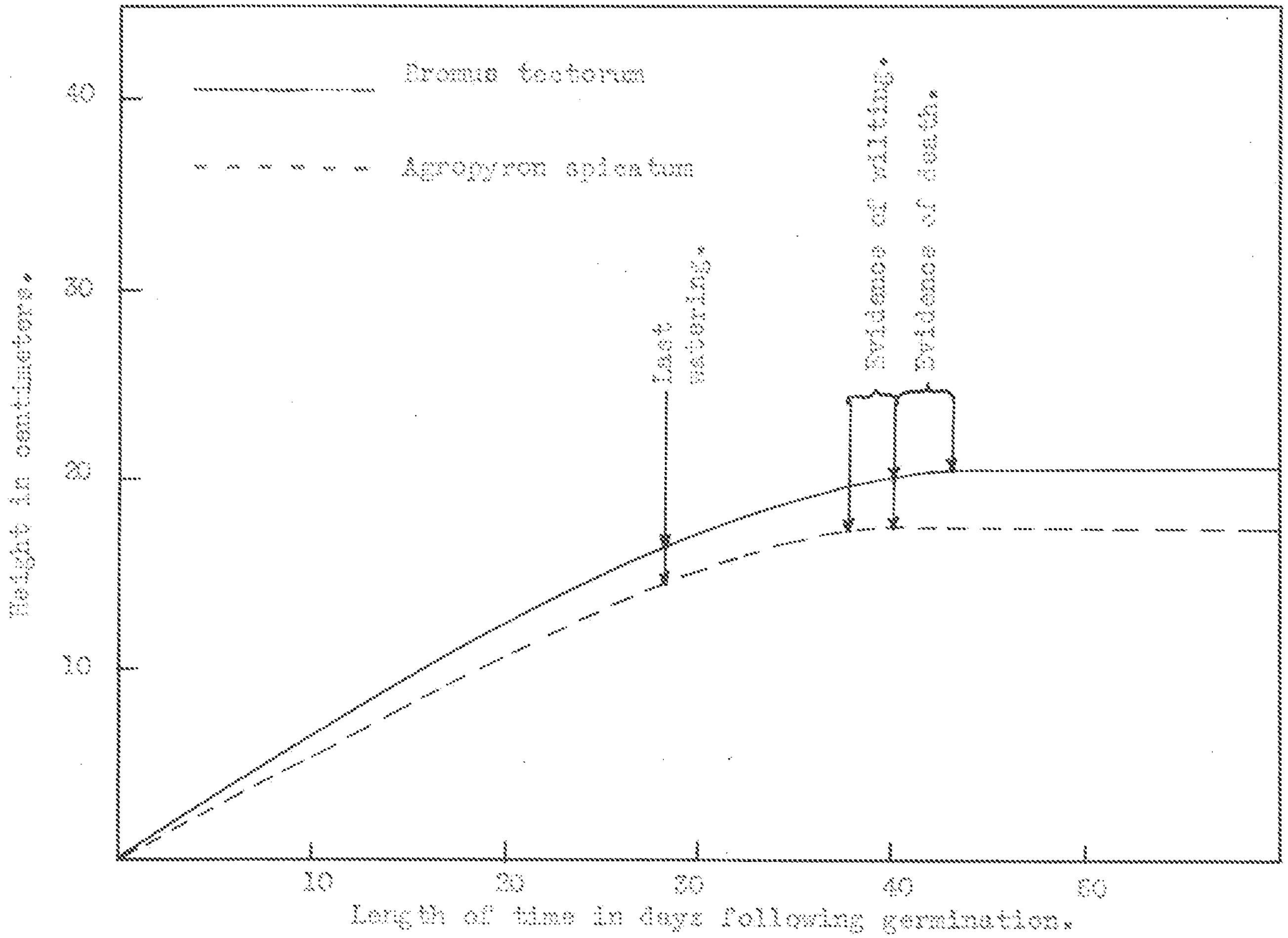

Fig. 4. - Rate of growth and effect of water shortage on seedlings of *Bromus tectorum* and *Agropyron spicatum*.

the fastest growth and react more slowly to adverse growing conditions resulting from a lack of water.

The ability of Bromus tectorum to produce an abundant seed crop, its ability to germinate in a very short time and its high degree of viability undoubtedly is advantageous to its survival in a natural stand provided seedlings alone offer the competition on a given area.

VEGETATIONAL STUDIES

To accurately follow any change in the vegetative cover of a given area it is necessary to make a series of observations on that area for a period of years. Where time is a limiting factor, however, observational studies of vegetational changes can be made on several areas which are subjected to or governed by an array of different environmental conditions through which any one area in a definite locality might be expected to pass in the developmental sequence of migration, ecesis, competition and stabilization. This latter method was used in a series of studies involving the succession and dominance of *Bromus tectorum*. In making these studies, sample plots were located at definite intervals in abandoned fields and on areas subjected to overgrazing, overgrazing and burning, moderate grazing and complete protection from any use. General observations were made on the area as a whole at the time the sample plots were laid out.

Succession. - Abandoned fields offer excellent opportunities for successional studies because they go back to the bare soil itself and the very start of plant growth and development. Old fields in which sample plots were placed had been abandoned for periods ranging from 1 to 10 years. In most cases they had not been used for any other purpose and the vegetation had remained undisturbed since the last cultivation. Depending on the number of years that have passed since they were last cultivated, these old fields show a definite trend in succession, in increased density and in the number of species present on the area.

In fields abandoned for 1 year *Bromus tectorum*, Russian thistle (*Salsola pestifera* A. Nels.) and Jim Hill mustard (*Norta altissima* (L.)

Baker) are the representative species. Fields abandoned for 2 years have practically the same plants present but lamb's-quarters (*Chenopodium album* L.) and prickly lettuce (*Lactuca scariola* L.) are also evident and *Bromus tectorum* begins to make a rapid increase in density on the area.

In fields abandoned for 5 years such biennials and perennials as Canada thistle (*Cirsium arvense* L.), yarrow (*Achillea lanulosa* Nutt.), sweetclovers (*Melilotus* spp.), stickseed (*Lappula occidentalis* (S. Wats.) Greene) and mullen (*Verbascum thapsus* L.) are common. At this time *Bromus tectorum* has definitely assumed a controlling influence over the entire plant community. Bunchgrass, in the form of *Poa secunda*, begins to appear in fields abandoned for 7 years. At the same time salsify (*Tragopogon pratensis* L.), lupine (*Lupinus* spp.) and goldenrod (*Solidago* sp.) begin to make up a component part of the vegetation.

Fields last cultivated 10 year ago show a still greater influx of *Poa secunda* as well as scattered individuals of *Agropyron spicatum* and *Festuca idahoensis*. These bunchgrasses are scatt'red and more in evidence near the edges of the fields. Farther from these outer limits or boundaries *Bromus tectorum* is still the dominant plant of the area.

On grass areas that have not been broken but which have been disturbed by overgrazing the return to the climax is much more rapid. Two years may, in some cases, be sufficient time for such areas to show progressive successional trends. Figure 3 shows a portion of range land that had been grazed by sheep and used as a lambing ground for 8 years prior to and including 1935. Since that time it has had complete protection from any use. In 1935 *Bromus tectorum* made up about 80 percent of the vegetation on the area. Readings of sample plots on the same land in 1937 showed that *Poa secunda* was the dominating species and occupied approximately 10 times more basal area than all other grasses combined--including *Bromus tectorum*.

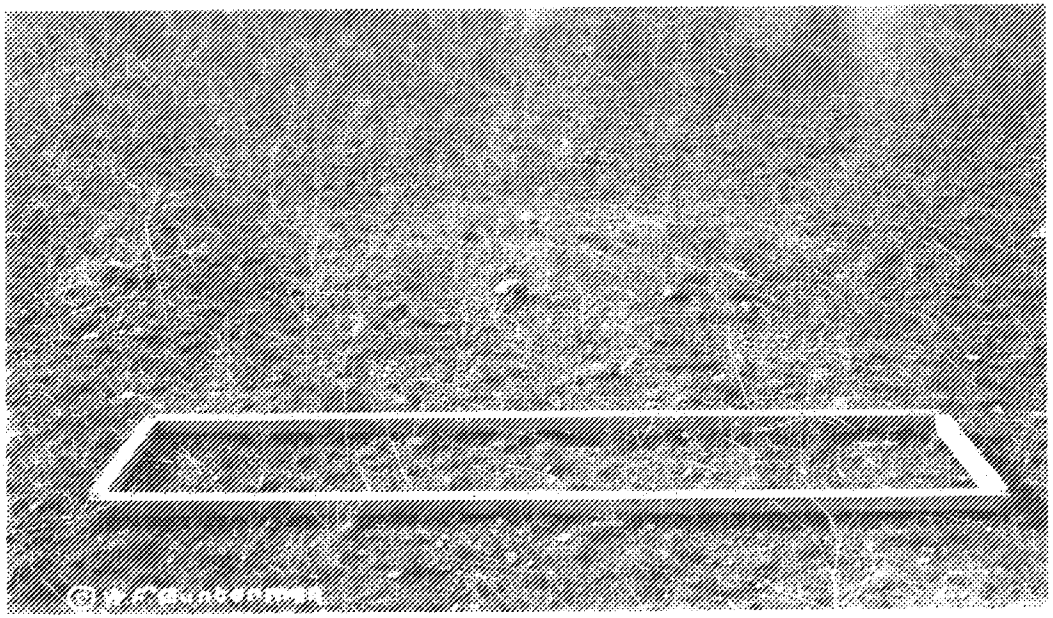

Fig. 6. - Area used as lambing and bed ground for 5 years but protected since 1935. Note clumps of *Poa secunda* in foreground.

These observations indicate that *Poa secunda*, as a representative bunchgrass species on overgrazed lands, has remarkable recuperative powers if it is given ample protection. In comparison with vegetational succession in abandoned fields, findings on all overgrazed lands indicate that, with complete protection and provided the rootstalks are not entirely destroyed, bunchgrasses as a rule will come back and assume their place in grassland types in a relatively short time.

Dominance.- In order to compare the dominance of different grasses on the areas studied, basal areas were determined by actual measurement of all those species falling within the sample plots. The diameters of the individual crowns were measured 1 inch above the surface of the ground and recorded to the nearest eighth inch. The basal areas were then computed and totaled by species for each sample plot. From the basal area figures the total area occupied by grasses in each sample plot was computed as was the percentage of the total area occupied by each species. Figures in Table 3 indicate the percentage of total area occupied by the more common grass species. Values less than .01 percent are not recorded.

Agropyron spicatum, as a climax species, indicates its greatest dominance on protected areas. Both its density and dominance decreases as environmental conditions become more adverse to natural growth and physiological functions. In contrast, *Bromus tectorum* is most dominant in abandoned fields and on overgrazed and burned areas. The reaction of *Poa secunda* to disturbing factors is that of a secondary or sub-climax species. When the climax grasses are first showing a downward trend in density and dominance, this species is making a temporary increase and only when the environmental conditions become extremely adverse through grazing and burning does it show a definite downward trend. *Festuca idahoensis* shows

Table 5. - Percentage of total ground area occupied by principal grass species computed from basal areas.

Species	Protected Areas	Moderately Grazed	Overgrazed	Overgrazed and Burned	7 year old Field
Bromus tectorum	Trace	.48	.18	.69	.70
Agropyron spicatum	2.81	2.67	Trace	Trace	Trace
Festuca idahoensis	1.86	.89	Trace	Trace	None
Poa secunda	.58	1.11	1.38	.10	.01
Stipa comata	Trace	Trace	Trace	Trace	None
Koeleria cristata	Trace	Trace	Trace	None	None
TOTALS	5.06	4.96	1.57	.80	.71

a reaction similar to *Agropyron spicatum*.

Basal diameters.- As a matter of interest and because the information was at hand from the sample plot readings and analyses, the average basal diameters of 4 of the major bunchgrasses were determined for areas subjected to different intensities of grazing or use (Table 4). These averages include all plants above the seedling stage and over an eighth inch in diameter. This accounts for the relative small diameter recorded for *Poa secunda*. Analysis of the values obtained in this study brings out very emphatically the fact that average diameters of the climax bunchgrasses are materially lessened as the environmental conditions become more adverse.

Table 4. - *Average basal diameters in inches of bunchgrasses on lands subjected to different treatment.*

Species	Intensity of Grazing or Treatment			
	Protected	Moderately Grazed	Overgrazed	Overgrazed and Burned
Agropyron spicatum	2.49	.93	.92	.88
Poa secunda	.58	.56	.54	.41
Festuca idahoensis	1.18	.83	.78	.64
Koeleria cristata	1.65	.65	.60	----

Discussion and conclusions. - When a field is abandoned the first plants to invade the area are those which are best adapted to or dependent entirely upon seed for establishment. It is natural, therefore, that such invasion should be by annual grasses or weeds.

In general the results of these studies and findings in abandoned fields are substantiated by the observations of Piemeisel[12] in the Salmon River country of Idaho. Judd,[9] although not noting the same species, made similar observations in the high plains country of western Nebraska. In all

instances there appears to be a gradual sequence of vegetation from a ruderal or annual weed stage to a late or perennial weed stage and finally to a stage in which perennial grasses are the dominant species.

There is no evidence available indicating the length of time that might be required for the old fields of eastern Montana to return to the grass climax. The few inroads made by bunchgrasses in fields abandoned for 10 years indicate that 30 years or more might be necessary to complete the cycle of succession. This is merely an estimate and does not pretend to take into consideration the unpredictable variables of nature such as cycles of drouth, precipitation and temperature, any abnormal change of which can easily modify or change the successional trend of a given vegetation.

It should be remembered that cultivation of grasslands usually involves the complete destruction of the plants. These grass species are then dependent upon seed dissemination from adjacent areas for reestablishment. The young seedlings so established are usually in direct competition with the more tolerant annuals and any successional trend towards the climax is rather slow.

In analyzing the sample plot findings of all areas, the behavior of the various indicator plants parallels those noted by Sampson in Utah.[13] The reactions of _Bromus tectorum_ and _Agropyron spicatum_ to any disturbing factor are definitely those of ecological extremes in plant succession. _Poa secunda_, as a sub-climax species, is more tolerant of adverse conditions, arising from overgrazing. Its reaction to repeated burnings is undoubtedly due to its comparative shallow root system.[13]

FORAGE VALUES

On many areas *Bromus tectorum* provides excellent forage during the spring and early summer months. Only when the plant becomes mature and the awns are prominent does it appear to be objectionable to grazing animals. Even then it is often cropped with relish, especially after the stems have been somewhat softened by rains.

To obtain some definite information of the forage value of this grass, the Northern Rocky Mountain Forest and Range Experiment Station, in cooperation with Regional Office of Region 1, conducted a feeding experiment with 3 horses in 1937 on an area which is part of the Forest Service winter range. The area selected for the experiment is an old field abandoned some 8 years ago and is located in the Flathead valley, about 60 miles northeast of Missoula at an elevation of approximately 4000 feet. The experimental pasture contains about 50.5 acres and is completely fenced. The vegetation is composed of approximately 90 percent *Bromus tectorum*. (Figure 6).

In writing of the experiment, Hurtt[8] records, "The horses were weighed and placed in the pasture in May and were kept there until December, being weighed at 14 day intervals during the period" . . . . The horses gained in weight through July, remained about the same during August, lost slightly in September, gained again in October and lost during November. "The fall gains were due to substantial growth of cheatgrass seedlings that occurred following the light rains of early October . . . On December 1 when the test closed the horses were still in fair condition but weights had dropped off . . . a net average loss of 53 pounds during the period of slightly more than 6 months."

The condition of the horses compared very favorable with those grazing at the same time in a bunchgrass pasture immediately adjacent to the experimental area. Had similar weight experiments been conducted with the horses pastured

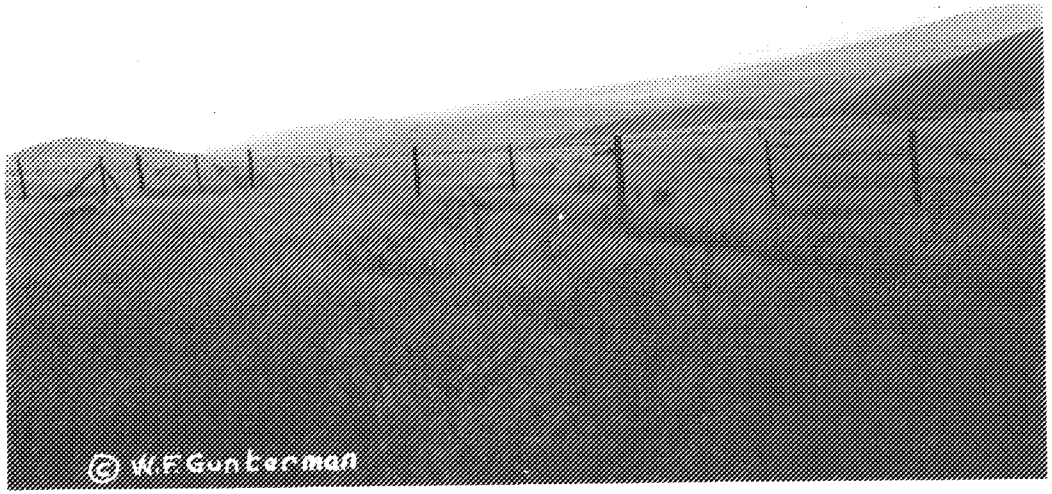

Fig. 6. - Bromus tectorum on experimental pasture. Enclosure in foreground. Note density of the grass.

on the bunchgrasses, the results would have been much more significant because a comparison would have been made with the feeding values of the so-called better grasses. Observations on the experimental area brought out the fact[8] that "Bromus tectorum supported horses at the rate of 1.7 acres per horse month and indicated that the carrying capacity may be relatively high at least during some seasons."

In line with the foregoing feeding experiment, the food value of Bromus tectorum as noted by chemical analysis is found to compare very favorably with native and other introduced grass species.[2] In many instances it is much better (Table 5). It should be remembered, however, that this high value is more common during the early life of the plant and lessens materially as the grass matures. In general, its value for grazing during the periods of the year when it is most palatable compensates somewhat the bad effects resulting from its occupancy of a given area on the range.

Table 5. - Comparative analyses of the forage value of Bromus tectorum and other grasses.

Species	Ash.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Protein.
Bromus tectorum	22.96	3.66	24.11	39.33	10.61
Agropyron spicatum	9.20	3.02	30.04	50.09	6.18
Poa secunda	8.09	4.11	31.43	51.07	9.30
Festuca scabrella	10.64	1.60	35.52	42.02	9.33
Koeleria cristata	7.65	3.03	33.94	46.98	8.20
Bouteloua gracilis	4.56	1.43	34.63	50.79	8.24
Bromus inermis	6.21	2.72	19.80	62.11	9.47
Stipa comata	6.70	2.31	34.40	49.73	6.86
Phleum pratense	7.34	1.94	37.44	46.30	6.98
Agrostis alba	11.40	1.61	32.17	47.62	7.30

CONTROL MEASURES

There is no well-established and certain method for eradication and control of *Bromus tectorum*. Burning and heavy spring grazing have been the common practices of most stockmen. On small areas seedings of other grass species and clean cultivation have been employed in an effort to control its spread. Seedings alone, of all these methods, has met with any semblance of success.

Burning. - Repeated burnings have not shown that this method of control might be employed successfully. In order to arrive at some definite conclusions as to the value of burning, a series of 25 plots were laid out southeast of Missoula and burned during the later part of September 1937. The plots supported a stand of *Bromus tectorum* and *Poa secunda* in about equal proportions. Fall germination of *Bromus tectorum* was already evident and growth was well advanced. These plots were burned with a gasoline torch and the entire surface vegetation was apparently consumed. In April, 1938, observations were taken on these burned plots and the number of seedlings of *Bromus tectorum* per square foot was recorded. On unburned plots immediately adjacent to the burned ones similar counts were made. Averages for the 25 burned plots showed 47 seedlings per square foot. The unburned plots averaged 58. In both cases the seedlings were the results of fall germination, those on the burned plots having become established after burning. Considering the conditions of extreme heat that were prevalent during the burning operations, these values indicate that this practice has little if any value as a method of controlling the spread and growth of the grass. The *Poa secunda* on the burned plots apparently was not thinned out by burning but it definitely lacked the vigor and growth of that on the unburned plots.

The results obtained by Sampson and Parker[14] in their work on St. John's wort and the germination of heat treated seed of that species suggested a similar experiment with *Bromus tectorum*. Seeds of this species were heated for periods of 5, 15, 30, and 60 minutes at temperatures of 80, 100, 125, and 150 degrees C. For comparison, seeds of *Agropyron spicatum*, *A. cristatum* and *Festuca idahoensis* were treated in the same manner. After heating, the seeds were germinated in the laboratory with the results as noted in Table 6.

The results obtained at 125 degrees C. are interesting in view of the fact that this is the approximate temperature noted by Sampson and Parker at ½ inch below the surface of the ground and below which depth few seeds could be expected to be found soon after maturity. At this temperature the germination of *Bromus tectorum*, although somewhat delayed, is still very high when heated for short periods. *Festuca idahoensis* is the only bunchgrass whose seed shows a semblance of germination after being exposed to this temperature. It would seem that, besides giving no definite results in the control of *Bromus tectorum*, burning is apt to be a detriment to the germination of seed of the native bunchgrasses.

Grazing. - On some areas attempts have been made to control the spread and growth of *Bromus tectorum* through the medium of overgrazing, especially in the spring. Analysis of the sample plot readings taken during the fall of 1937 (Table 3) indicates that such practices tend to encourage rather than control the grass. In all cases of overgrazing or misuse of range lands there is a greater percentage of this grass than on areas where grazing was moderate or restricted.

Seeding. - Where local infestations are confined to relatively small acreages of abandoned fields, seeding these areas to other species has been successful in many instances in controlling *Bromus tectorum*. For such purposes, *Agropyron*

Table 6. - Germination percentages for seed treated at varying degrees of temperature.

Species.	Check Germination.	Minutes Treated.	Temperatures 80° C	100° C	125°C	150°C
Bromus tectorum		5	98.00	98.25	87.25	0.00
		15	99.00	100.00	48.50	0.00
		30	99.00	100.00	26.25	0.00
	99.67	60	99.25	99.50	0.00	0.00
Agropyron spicatum		5	82.25	88.50	0.00	0.00
		15	80.00	56.00	0.00	0.00
		30	80.50	20.75	0.00	0.00
	86.50	60	80.50	5.50	0.00	0.00
Agropyron cristatum		5	94.00	84.50	0.75	0.00
		15	93.25	78.00	0.00	0.00
		30	93.25	29.75	0.00	0.00
	96.25	60	94.25	11.50	0.00	0.00
Festuca idahoensis		5	91.00	80.75	13.25	0.00
		15	94.25	83.00	0.00	0.00
		30	93.50	87.00	0.00	0.00
	94.50	60	93.25	73.25	0.00	0.00

cristatum and smooth brome (*Bromus inermis* Leyss.) are generally used. The over-wintering growth habits of *Bromus tectorum*, however, offers a handicap of competition which is often too difficult to overcome, especially on well stocked areas. Under such conditions annual plantings over a period of several years may be necessary to insure establishment of the desired species. The costs of such a procedure would be prohibitive except, probably, on small acreages of pasture that might be used for lambing, calving or breeding purposes.

It is an established fact that *Bromus tectorum* reproduces entirely or nearly so during the fall months of any given year. Discing or plowing in the late fall after the grass has become established followed by immediate seeding may be conducive to more successful plantings. Such a method is worthy of consideration because a great many *Bromus tectorum* seedlings would be killed out and less competition would be afforded the planted species during the period of germination and establishment the following spring.

Cultivation. - Clean cultivation in the fall or early spring has been advanced as a method of control.[10] This method is practical only on small acreages and unless there is a subsequent planting of some other species, the control would be merely temporary. In many cases, seeding of abandoned fields and depleted range lands, especially on small acreages, has been used successfully as a method of control.

Other Methods. - In a series of experiments by Massey* at Cornell, smut was artificially introduced on *Bromus tectorum* in an effort to control its spread. Some success was evident in that the setting of seed was eliminated

* Information from correspondence between L. M. Massey, Department of Plant Pathology, Cornell University and L. C. Hurtt, Northern Rocky Mountain Forest and Range Experiment Station.

on many plants. Such a practice might be used successfully and with a minimum of cost on small tilled areas where it is desired to control Bromus tectorum as a weed. It is impractical, however, on the extensive areas common to our range lands.

Discussion and Conclusion. - Because of its wide spread infestation, apparent tolerance to range malpractices, high degree of seed viability and growth habits, it is doubtful if eradication or control of Bromus tectorum can be accomplished on any large area. While it affords a management problem on a large acreage of our range lands, in many cases its presence should be condoned as being beneficial rather than detrimental. Its tendency to become easily established on bare soils make it a beneficial controlling factor on lands subject to erosion. In abandoned fields it serves as a nurse crop for the influx of more valuable species. On many acres of range land throughout the western states it furnishes excellent spring forage for all classes of livestock.

As a general rule, there should be no mechanical method of control attempted unless some provision is made at the same time to replace the grass with another species of an equal or greater value.

SUMMARY

Bromus tectorum L., known most commonly as cheatgrass, is one of the most widely spread grass species that has been introduced into this country. The grass is usually found growing on areas where the native vegetation has been reduced or changed by environmental conditions.

Temporary reduction of individual stands through smut infestations is common at several year intervals.

Seeds of the grass mature during the summer and early fall months, fall to the ground and germinate immediately upon the advent of favorable weather conditions. The resulting plant over-winters as a seedling. Seeds are very viable shortly after maturity, showing as high as 99.75 per cent germination.

The germination per cent of over-wintering seeds was very low and vegetative characteristics indicate that the plant might act entirely as a winter annual and not complete its life cycle in any one year.

In comparison with seedlings of *Agropyron spicatum*, individual plants of *Bromus tectorum* show a more vigorous growth of both roots and shoots. Under control competitive conditions with *Agropyron spicatum*, seedlings of *Bromus tectorum* also show better development and react more slowly to unfavorable growing conditions.

In abandoned fields, *Bromus tectorum* is one of the first plants to become established and is the first dominant on such areas.

On overgrazed lands, where annual grasses and weeds are common, the return to the bunchgrass climax is fairly rapid provided the perennial species have not been subjected to too much damage, especially to the rootstalks.

The percentage of total area occupied by the climax species and their average basal area is materially lessened with increased intensity of grazing

and the degree of closure of the area.

Actual feeding tests with _Bromus tectorum_ prove that the grass has definite values as a forage plant, especially in the spring and early summer and in the fall following the late season's growth. Chemical analysis of the food value of the grass compares very favorably with that of the native bunchgrasses and other introduced species.

Burning offers little value as a method of controlling the spread and growth of _Bromus tectorum_. It may have a detrimental effect on a given area through the destruction of the other grasses present. The seed of _Bromus tectorum_ is less susceptible to the damaging effects of heat than that of the native grasses.

Seeding has, in many cases, been used successfully as a control measure.

The success of controlling the grass by overgrazing and cultivation is questionable. The latter method, in combination with seeding, may reasonably insure more successful plantings.

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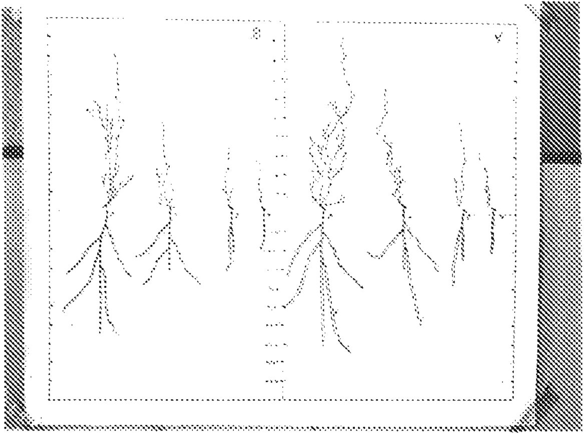

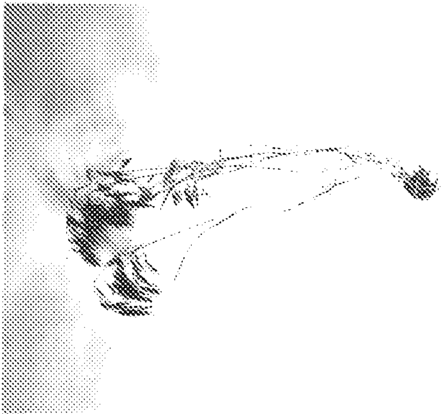

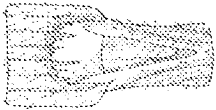

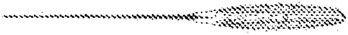

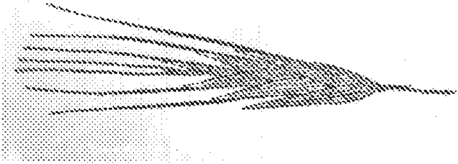

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